HEALTH AND SAFETY OF LABORATORY WORKERS IN CANADA

A REVIEW OF THE LITERATURE

A Report from the Working Group on

Health Surveillance and Laboratory Safety

to the

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FOREWORD

In March 1979 a Federal-Provincial Working Group on Health Surveillance and Laboratory Safety was established as a consequence of concerns expressed by the Advisory Committee on Environmental and Occupational Health and the Conference of Deputy Ministers of Health. In order to facilitate the task assigned to this Work Group a literature review was undertaken.

This review of recent literature is intended to provide a substantive base for those charged with the implementation of health and safety programs for laboratory workers. While it addresses a wide range of laboratory operations, from the physical to the biological sciences, there may be many topics and situations that are likely to be encountered where there are few precedents, and where the two most valuable assets to a laboratory worker, common sense and caution, must be invoked.

This document has been reviewed and approved by the Working Group on Health Surveillance and Laboratory Safety. Acknowledgement for the preparation of this report is made to Dr. J.R. Withey, A/Chief, Toxicology Division, Food Directorate, Health Protection Branch.

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INTRODUCTION

Webster's dictionary (1968) defines a laboratory as: "A place devoted to experimental study in any branch of natural science or to the application of scientific principles in testing and analysis or in the preparation, on a small scale, of drugs, chemicals, explosives or other chemical and biological substances." This definition, while covering the majority of laboratory facilities, does leave open the question of whether it includes the routine monitoring laboratory or quality control facility, so commonly encountered in large industrial organizations. The garage mechanic, checking and replacing the spent acid in a car battery, could also quite legitimately be considered as a technician performing a laboratory operation.

In the majority of published communications on the subject of the health and safety of laboratory workers, readers are often left to their own concept as to the nature of the particular laboratory environment under discussion. A comparatively recent contribution in an authoritative publication (Fawcett, 1972) illustrates the dilemma by abandoning any attempt at a comprehensive definition and limiting the definition of "laboratory operations" to those in which "toxic, corrosive, flammable and explosive" substances are handled "often in fragile glass apparatus, ionising and other radiations are studied and used, electrical apparatus, at lethal voltages may be assembled, tested and operated, and disease-infested tissue and animals may have to be examined, tested and assessed."

Whatever an acceptable definition may be, laboratory operations certainly involve procedures and equipment that have potentially harmful consequences if improperly handled. Such consequences are not limited to the operator or to an individual, but can involve unsuspecting colleagues and support staff.

This review of the recent literature is intended to provide a substantive base for those charged with the implementation of health and safety programs for laboratory workers. While it addresses a wide range of laboratory operations, from the physical to the biological sciences, there may be many topics and situations that are likely to be encountered where there are few precedents and where the two most valuable assets to a laboratory worker, common sense and caution, must be invoked.

THE LITERATURE SEARCH

With a couple of general papers on the subject and the selection of a dozen or so key works, a Medlars literature search through Medline, Toxline etc. turned up a total of 788 references (with some iteration). Photocopies were requested of papers considered to be highly relevant for the documentation of the problems and current thoughts on health and safety in the laboratory environment.

A rough classification of these reports was attempted, using the following headings, with the number of papers in each area being indicated:

(a)	Health and Medical Aspects	(19)
(b)	Carcinogens	(6)
(c)	Chemicals	(34)
(d)	Physical	(5)
(e)	Radiation	(5)
(f)	Microbiology	(57)
(g)	Animals	(2)
(h)	General Aspects of Laboratory Safety	(20)
(i)	Miscellaneous	(5)

for a total of 153 papers.

A very high proportion of these papers relate to microbiological hazards, associated with hospital laboratories and pathology laboratories. Two principal items appear to be the frequent outbreaks of hepatitis and the implications of a recent smallpox death in the United Kingdom. A majority of these references appeared as letters in "The Lancet".

The "Journal of Chemical Education" devotes a special section to "Safety in the Chemical Laboratory". The issue for February 1970 contains the 60th contribution of this series. The letters in "Chemistry in Britain" nearly always contain one or two that relate especially to recent hazardous experiences with new and exotic chemicals (e.g. N-chlorinated phosphorus amides), but there is also a smattering of opinions of a "political and philosophical" nature and the occasional reminder of problems with well-known chemicals like mercury and potassium permanganate, or an assessment of the physical hazards associated with laboratory glassware.

Probably the most active field in current legislation concerns the safe handling and use of known or potential carcinogens. The U.S. Federal Agencies of OSHA, NIOSH and NCI* are currently producing handbooks covering the use of carcinogenic materials in situations ranging from continuous use in the workplace to the occasional use in laboratories. Philosophical and political questions like "What is an acceptable risk" (i.e. in terms of allowable exposure) are having to be faced squarely in order to meet the needs of the real world.

It might be of interest to point out that the question of acceptable risk has been addressed in several recent publications (Cornfield et al., 1978; Federal Register, 1979). An acceptable risk, for carcinogens in food and water, of between one in 10^8 and 10^5 has been considered. While such probabilities this small are difficult to interpret physically, Cornfield points out that a probability of death of 1 in 10^6, using 1974 statistics, would be predicted for:

2 hr. of nonfarm employment,
a 35-mile automobile ride,
or 43 round trips on a school bus.

*Occupational Safety and Health Association, National Institute of Occupational Safety and Health and National Cancer Institute.

A very real message, however, appeared in a letter to the British Medical Journal (Pilsworth, 1979) in which he criticized some of the recommendations of the Howie Report (1978). In his letter, Pilsworth claimed that the report was compiled by a group that was "lamentably short of working hospital pathologists". He also pointed out that "the report produced a dogmatic and mandatory list of precautions to be taken against risks that have hardly been identified and far less quantified". Further, he expressed concern for the possibility that "a medical laboratory scientific officer less than half-way towards qualification may be appointed as a laboratory safety representative".

It would seem fair to conclude that very careful thought should be given to the formulation of realistic goals in safety regulations and in the choice of safety personnel. On the other hand, safety standards must not be reduced as a consequence of financial constraints.

In reviewing the literature on health and safety in the laboratory environment some general references, that cover a wide spectrum of laboratory operations, have been considered and an attempt was made to discuss the findings of reports under the headings given on page 3. Special attention has been given to those communications that addressed the Canadian situation.

General Literature

One of the most widely cited reference texts on laboratory safety is the "Handbook of Laboratory Safety", produced by the Chemical Rubber Company (Steere, 1971). The Treasury Board of the federal government produced a "Safety Guide for Laboratory Operations" in 1973, and a second edition of this publication as Treasury Board Guide 5-1 appeared in 1977*. While this manual presents and

*The Personnel Policy Branch, Health and Safety Group, Place Bell Canada, 18th Floor, S.E., Elgin Street, Ottawa, Ontario, K1A 0R5

discusses guidelines as opposed to mandatory requirements, and does not address the question of health monitoring to any great extent, it does provide a number of Canadian sources for aspects relating to specific codes concerning laboratory operations in Canada. Among the more important of these are:

Technical Information Bulletins of the Dominion Fire Commissionerv

Fire Protection Engineering Standards[v]

Dangerous Substances Safety Standard. TB-STD 3-14**

Personal Protective Equipment Safety Standard, TB-STD 3-14**

Hazardous Confined Spaced Safety Standard, TB-STD 3-7**

Periodic Health Evaluations Standard, TB-STD 3-13**

Recommended Safety Procedures for the Installation and Use of Radio-frequency and Microwave Devices in the Frequency Range 10MHz-300GHz, RPB-SC-6[x]

Installation and Safety Procedures for the Use of X-Rays in Medical Therapy, RPB-SC-1[x]

Policy Respecting the Use of Radionuclides in Humans, RPB-SC-14[x]

Recommended Safety Procedures for the Selection, Installation and Use of Active Metal Detectors, RPB-SC-18[x]

X-Ray Equipment in Medical Diagnosis, Part A: Recommended Safety Procedures for Installation and Use, RPB-SC-20A[x]

Recommended Safety Procedures for the Selection, Installation and Use of Baggage Inspection X-Ray Equipment, RPB-SC-21[x]

Radiation Protection in Dental Practice, Recommended Safety Procedures for Installation and Use of Dental X-Ray Equipment, RPB-SC-22[x]

Guidelines for the Safe Use of Ultrasound -- Part I: Medical and Paramedical Applications, RPB-SC-23[x]

Guidelines for the Safe Use of Ultrasound -- Part II: Industrial and Commercial Applications, RPB-SC-24[x]

Most industrial and large government laboratory facilities have produced safety manuals for their own specific needs. While they usually cover aspects of personal protection, the handling of hazardous chemical and biological materials, waste disposal and general laboratory safety, few have dealt with any kind of programs for health monitoring. Those that follow are cited and the publisher and source are given in the list of references at the end of this section:

The National Institute of Environmental Health Sciences Safety and Health Manual

Accident Prevention Manual for Industrial Operations

Industrial Ventilation Manual

Threshold Limit Values

Industrial Hygiene Practices Guide for Laboratory Hood Ventilation

Chemical Safety Data Sheets

Safety Measures in Chemical Laboratories

Dangerous Properties of Industrial Materials

B.W. Safety Manual

C.S.L.T. Safety Manual

Laboratory Safety at the Center for Disease Control

Laboratory Waste Disposal Manual

Poisons: Properties, Chemical Identification, Symptoms and Emergency Treatment.

These publications are obtainable from:

[†]The Dominion Fire Commissioner, Public Works Canada, Sir Charles Tupper Building, Confederation Heights, Riverside Drive, Ottawa, Ontario, K1A 0M2.

[x]Health Protection Branch, Radiation Protection Bureau, Brookfield Road, Confederation Heights, Ottawa, Ontario, K1A 1C1.

Two important documents have reached the draft stage that should not really be cited, but are included here because the final documents will be valuable resource material. The Working Group were privileged to receive the first draft of a report by a committee of the National Academy of Sciences - National Research Council, chaired by Dr. Herbert O. House. This report, entitled "Prudent Practices for Handling Hazardous Chemicals in Laboratories",* was obtained following a response to an announcement in Occupational Health and Safety Letter (1979). The report, of more than 300 pages, reviews the epidemiologic studies concerning chronic illness among laboratory personnel, and addresses problems such as the handling of known and suspect human carcinogens and the disposal of chemical waste.

A revised draft (June 5, 1979) of the "Guidelines for the Laboratory Use of Chemical Substances Posing a Potential Occupational Carcinogenic Risk" was received. This document was produced by the Laboratory Chemical Carcinogen Safety Standards Subcommittee of the U.S. Department of Health Education and Welfare Committee to Coordinate Toxicology and Related Programs. A copy of the transcript of the discussions and public comments was also received. The latter document, arising from a joint meeting of government, industry and academia on July 24, 1979, provided some discussion on controversial topics like acceptable risk, the nature of periodic health examinations, adequate ventilation, fume hood operation, records and inventories and epidemiology studies. An excellent article on safety, that is especially relevant to all laboratory workers, appeared recently (Hartley and Booth, 1977).

*This document has now been published (December, 1980) and is available from the Assembly of Mathematical and Physical Sciences, National Research Council, National Academy Press, Washington, D.C.

Medical and Health Aspects

A number of epidemiology studies involving personnel from laboratories have been published. While these are critically reviewed elsewhere in this report, they are included here for the sake of completeness. In a cohort of 857 men graduating in the sciences between 1930 and 1950, and for which 93 deaths were recorded has been published recently (Olin, 1978). There was a significant increase in cancer (leukemia/malignant lymphomas and of urogenital tumors). A study of Danish clinical chemistry laboratory workers (Udall, 1974) revealed that hepatitis, burns and cuts were the most common laboratory hazards and that the number of personal injuries seemed unnecessarily high. Harrington and Shannon's (1977) survey of British medical laboratories, involving 24 000 medical laboratory workers, recommended that urgent consideration should be given to establishing regulations for codes of safe practice rather than relying merely on recommendations as at present. These authors claimed that 65% of the laboratories in England and Wales allowed mouth pipetting and that the use of protective clothing is rarely compulsory.

In a previous report, these same authors reviewed the literature and obtained other data to assess the significance of the mortality of pathologists and medical laboratory technicians (Harrington and Shannon, 1975). They found that suicide was the most common cause of death among female technicians and suggested that a facile access to lethal chemicals may be a determining factor. Pathologists also had a suicide rate that exceeded those of all medical practitioners. In an earlier report (Reid, 1973) it was noted that the incidence of tuberculosis among medical laboratory workers was higher than expected. Although the acquisition of other infectious diseases could not be assessed in the same way, it was possible to conclude that hepatitis was an occupational hazard for tuberculosis workers as was shigellosis (Anon, 1979a).

In a contribution to Chemistry in Britain (Anon 1979b) a review of the report by the Chief Inspector of Factories in the publication: "Health and safety - manufacturing and service industries (1977)," noted that inspectors were constantly surprised by the poor quality of safety and health information provided to top management. It went on to say that the Director of the newly-formed National Industry Groups will ensure consistency of enforcement standards, coordi nate initiatives and priorities, disseminate technical information and develop relations with employers and trade unions in the industry (one group comes under the heading of "Chemical"). An earlier paper in the same journal announced the initiation of an epidemiology survey of health and patterns of mortality among members of the Royal Institute of Chemistry (McGinty, 1978). Some previous epidemiological retrospective studies were reviewed in this paper and their limitations and reservations were discussed.

Specific studies indicating the susceptibility of laboratory workers to health hazards arising from their working environment are not plentiful but, as the following examples illustrate, are sufficient to encourage further work in this field. Cultured lymphocytes from 73 workers in chemical laboratories and printing works were found to have a significantly increased frequency of chromatid and isochromatid breaks (Funes-Cravioto et al., 1977). In a recent review, based upon two studies of the congenital malformations in the offspring of nurses, Yager, (1973), cited evidence for the presence of teratogenic agents in the hospital laboratory and environment, and concluded that the chances of exposure of pregnant women to these agents was considered to be high.

The epidemiology of hepatitis B in hospital personnel suggested that subclinical infection predominated within the disease spectrum for this population (Pattison et al., 1975). Only 14% of those with serological evidence of hepatitis B infection displayed evidence of overt illness. These data did not correlate with an

exposure to patients infected with hepatitis B nor with previous blood transfusions. In a commentary of the epidemiology of enteric infections acquired in the laboratory (Dull, 1977) a paper by Dr. Robert Pike was reviewed. This gave an account of laboratory diseases in the nineteenth and twentieth centuries together with a special survey of experiences through 1974 Pike, 1976).* In more than 4000 cases of laboratory-associated infection, a case fatality rate of about four per cent was recorded. In more recent years a common cause for laboratory epidemics was a centrifuge-related aerosol of the organisms of brucella and psittacosis. The etiologies of the 4000 cases revealed that 43% were caused by bacteria and 27% by viruses.

Only one paper was obtained in the search for discussion on the question of medical monitoring (Robinson, 1973). In this paper the author pointed out that a continuous monitoring of the atmosphere in the workplace, leading to an assumption that "acceptably safe" conditions prevailed if these levels were below the Threshold Limit Values established by the American Conference of Industrial Hygienists, has produced hazardous levels of these materials in exposed workers. Conversely, some monitoring programs have yielded information that would suggest that exposed workers have been exposed to levels higher than the Threshold Limit Value without symptoms or any apparent impairment of health attributable thereto.

The author goes on to conclude that "rigidly" imposed government "standards" would seriously hamper an industrial physician should these take precedence over his professional judgements. Medical monitoring was defined as a procedure in which biological samples, taken from exposed workers, were analysed

* This paper has been updated: Pike, R.M. (1979) Laboratory associated infections: incidence, fatalities, causes and prevention. Ann Rev. Microbiol., 33, 41-66.

and an interpretation of the significance to health used to formulate recommendations aimed at preserving or restoring the health of individual workers. Respiratory surveys in industry with a mobile facility has been described (Field et al., 1976). The instrumentation used in the testing of this facility with 496 employees showed that a series of complex lung function tests, including body plethysmography and the insertion of an oesophageal balloon, was acceptable to 98.4% of those tested.

The U.S. National Institute of Occupational Safety and Health (NIOSH) has a hazard evaluation and technical assistance program that has yielded a number of interesting reports. The two that are cited here (1974 and 1977) concern investigations carried out by a team of specialists in photographic laboratories and in a museum facility where artifacts were restored. Many other reports of this kind are available from NIOSH. An important international comparison of occupational health standards (Holmberg and Winell, 1977) covered a wide range of literature and concluded that the differences among countries in the numerical limit values for toxic substances were largely due to differences in definitions, biomedical criteria, technical feasibility and sociopolitical judgements.

Chemicals

This section will consider some aspects of concern with regards to the handling and disposal of chemicals in the laboratory. The section that follows will deal with those chemicals that are either human or laboratory animal known or potential carcinogens.

In a recent article (Steere, 1971b) the identification, classification and labelling of hazardous chemicals was discussed in the context of new U.S. Federal Standards. Corrosives, irritants, sensitizers and toxic substances are considered in the context of the U.S. Federal Standard No. 313 (1971). Illustrations

of the labels required (in the U.S.) are included in this reference. A labelling and control system for toxic materials in a research facility delineates the hazards associated with particular materials, and also facilitates the appropriate workplace surveillance during its use and subsequent disposal (Porter et al. 1977).

An excellent review on safety in the chemical laboratory appeared recently in Analytical Chemistry (Michelotti, 1979). This review considered flammable liquids, corrosive chemicals, a variety of insidious hazards and the hazards of specific classes of compounds such as azides and peroxides. Special attention was given to safety aspects like fire fighting, safety showers, spill control and the handling of compressed gases and cryogenic liquids. This paper mentioned the circumstances leading to an explosion caused by perchloric acid that killed 15 people and injured 400 (Harris, 1949). Toxic hazards in chemical laboratories and the means of reducing them have been discussed in a number of communications (Park, 1966; Lippert and Glas, 1970; Jones, 1975; Porter et al., 1978; Hill et al., 1978).

Many hazards associated with specific chemicals or laboratory operations have been reported. Some of these concerns prove to be somewhat controversial, as was demonstrated by the exchange on the hazards associated with the handling of Xylene (Bush and Nelson 1977; Clark, W.E., 1977). The questions as to the hazard posed by orthotoluidine and dianisidine were also discussed in an editorial (Collier, 1974), and the question of the carcinogenicity of magenta and related dyes has been addressed (Howe, 1977).

As new chemical compounds and derivatives are produced by the thousands each year, they have provided new evidence of hazards as a consequence of their toxic, corrosive, flammable or explosive properties; so too have communications that alert the scientific world as they appear in print. Some, for example, like that on hexavalent chromium compounds (Katchen and Notani-Sharma, 1978)

relate to compounds that have been known for some time. The publication "Chemistry in Britain" has included letters alerting chemists to hazardous laboratory experiences of all kinds in nearly all its issues over the past few years. Those that have appeared in recent issues have dealt with the problems of exposure to anaesthetics (Halliday, 1978), chloracetoxime (Maytum, 1978), potassium permanganate (Craven, 1979), liquid nitrogen (Baker, 1979), bismuth (Falkner, 1979), N-chlorinated phosphorus amides (Walker, 1979), glassware (Chalmers, 1979), sodium-potassium alloys (Ingham, 1978), tetrabutylammonium Phipermanganate (Morris and Mills, 1978), powerful methylating agents (Alder et al., 1978), and the carcinogenicity of alkylating agents (Ashby, 1978). These are but a few of the many hundreds of examples that research workers and laboratory personnel should consider as "required reading" in the interests of laboratory health and safety.

All aspects of laboratory safety have been considered in an ongoing series published in the "Journal of Chemical Education". Well over one hundred articles have appeared, one of the more recent appearing in the December 1979 issue (Reich and Harris, 1979). Some chemical catalogues also include sections on laboratory safety and the safe handling and disposal of dangerous chemicals (B.D.H., 1979). Chemical companies also run courses and seminars on the safe handling and disposal of chemicals. The J.T. Baker Company probably has the most extensive range, with courses arranged in 29 locations in the summer and fall of 1980.*

Carcinogens

There is, perhaps, good reason to place those chemicals that have been considered to have a proven or suspected carcinogenic potential for man in a separate class. This rationale has grown from an increased understanding of the

*The Hazardous Chemical Safety Seminar and Workshop, J.T. Baker Co. Phillipsburg, New Jersey, 08865.

mechanism of carcinogenesis and may be based on human epidemiological evidence, in vitro and animal tests or from a similarity in chemical structure to known carcinogens (Hiatt et al., 1977). Maugh (1978a,b) has reviewed the literature on chemical carcinogens and reported that only 26 chemicals are known to be carcinogenic for man, while 56 others are suspect human carcinogens, although the epidemiological evidence is less definitive. Some seven thousand compounds have been tested for carcinogenicity in various animal models and, of these, a little more than 1500 have been reported to be carcinogenic. A major impact in the consideration of carcinogens as a separate class arises as a consequence of their unusually high potency (a single low dose exposure to asbestos or vinyl chloride can result in the subsequent development of tumors), the long latency of the ultimate effect, the controversy as to the best mathematical model for dose-effect relationships and of the question "what is an acceptable risk" (Proposed System for Food Safety Assessment, 1978; Cornfield et al., 1978). The International Agency for Research on Cancer has also played an important role in the evaluation of chemical carcinogens (Tomatis et al., 1978).

The U.S. Occupational Safety and Health Administration (OSHA) has issued standards for laboratory operations when working with carcinogens (Federal Regulations, 1974). The interpretation and application of these regulations were discussed in a recent communication (Rappaport and Campbell, 1976). Long-term feeding studies with laboratory animals, usually lasting for the duration of the animals' life span, present a special hazard to laboratory personnel. In a controlled study using a chemical tracer added to the food supply, the marker compound was found to have contaminated not only clothing and equipment, but all surfaces of the experimental room and the corridors leading to and from it (Sansone et al., 1977).

The carcinogenic hazards found in a variety of laboratory environments have been considered. Hospital laboratories, cancer research laboratories and teaching laboratories in schools were discussed, not only with respect to laboratory workers, but also from the standpoint of human exposure to some clinical tests, such as the determination of fecal blood and blood glucose (George and Searle, 1976). A number of editorials have also considered carcinogenic hazards in laboratories and the regulation of exposure to them (Anon, 1970; Abelson, 1978).

Selected references on laboratory design, the use of hoods and the specific hazards of common laboratory procedures in the field of microbiology were reviewed, and their application to laboratory work with carcinogens was suggested (Sansone and Slein, 1976). The U.S. Department of Health, Education and Welfare has recently distributed (June 5, 1979) a draft entitled "Guidelines for the Laboratory Use of Chemical Substances Posing a Potential Occupational Carcinogenic Risk", and held a meeting where public comment was invited (July 24, 1979). This document, and the transcript of the public hearing, covered aspects of medical surveillance, cost effectiveness, duties and responsibilities of scientists and safety officers, as well as reviewing some of the available literature on epidemiology and the laboratory environment. A most important aspect, that of "mandatory standards" for some issues as opposed to "guidelines" was also addressed. There appears to be a strong feeling that guidelines in combination with professional judgement provide a superior management and work climate as opposed to strictly enforced laws.

Physical Hazards

Of the physical hazards encountered in the laboratory, fire must represent the one that is the most frequently encountered. The responsibility for

all aspects related to fire safety has been assigned to the Dominion Fire Commissioner, Canada, and his office has numerous publications covering special circumstances. Of course, some laboratory chemicals have been identified as being especially hazardous due to their explosive or combustible properties. Several articles in the series "Safety in the Chemical Laboratory" published in the "Journal of Chemical Education" were devoted to the subject of fire safety in laboratories (Steere, 1975).

Compressed gas cylinders, as portable sources of a variety of gases in analytical laboratories, hospital wards and operating rooms, can cause serious accidents that vary from fractured limbs due to improperly secured cylinders falling, to explosions arising from insecure valves or the fracture of cylinders that have been dropped. Health hazards may also arise from leaky valves or connections on cylinders containing, for example, hydrogen fluoride or hydrogen sulfide, and this aspect has been considered in several articles (Steere, 1975; Conk, et al. 1977). It would appear, from these published reports, that standards have been set for the maximum number of cylinders to be stored in one room, as well as the maximum length of time for which a cylinder should be retained. A dramatic episode was reported in which a discarded cylinder was "quietly being burned" to dispose of its contents - monovinylacetylene. In the explosion that inevitably followed, the cylinder walls luckily opened up like a peeled banana instead of fragmenting (Fawcett, 1972). A report on the explosion of a cylinder containing hydrogen fluoride has also appeared (Zeihlke et al. 1969). Examples of this type rarely appear in print although one must suspect that they happen.

Accidents involving some laboratory instrumentation have been reviewed recently (Kennedy, 1979). The "spin off" type of accident with laboratory centrifuges was carefully analyzed. A Canadian report of an accident involving an explosion in a waste pipe system as a consequence of the reaction of the copper

pipe material and azides, that had been poured down the sink, was also cited in this paper (Merry, 1973). A lack of proper maintenance was cited as the major cause of instrumentation accidents. An unusual type of hazard was pointed out in a letter to "The Lancet" (Carstairs and Coates, 1974). Various types of vacuum tubes have been used for some time to collect specimens of venous blood. Droplets, sometimes as aerosol dispersions, can apparently be generated when opening these containers. Average "spills" from these devices was 0.5 µl which, if the blood were contaminated with pathogenic organisms, could prove to be a source of serious infection.

Radiation

Ionizing radiation is capable of producing chemical changes in the complex biological molecules of living cells. The maximum permissible doses of ionizing radiation have been carefully defined in terms of the systems that are exposed (ICRP 26). Exposures are reduced during pregnancy for designated workers. The maximum whole body dose commitment is 50 millisieverts (5 rem) per year to an atomic radiation worker, with the proviso that doses should be kept as low as reasonably achievable.

In the laboratory, exposure to ionizing radiation may result from the use of radionuclides or x-ray emitting devices. The use of radioactive isotopes in Canada is controlled by the Atomic Energy Control Board. The Radiation Protection Bureau of National Health and Welfare Canada has published several safety codes dealing with the safe use of ionizing and non-ionizing radiation (see page 6). These Safety Codes dealing with ionizing radiation are based on the recommendations of the International Commission on Radiological Protection (ICRP), and are designed to ensure that the dose to workers is kept within acceptable limits. The ICRP is an international body of acknowledged experts in the field of radiation protection.

The role laboratory managers in the protection of personnel where radiation sources are used has been reviewed by Odland, 1969. This author suggested that a more sophisticated laboratory support program, directed towards health and safety surveillance might be required. Depending on the radionuclides used, and their activities, this program might include personnel dosimetry, radiochemical assay techniques, various counting facilities, on-line computer facilities and health support staff, which would include medical consultants. Health practices in laboratories using ^{14}C and ^{3}H radioisotopes merit special attention because of their widespread distribution in the body and the long radioactive half-life of ^{14}C (Berger and Cloutier, 1972). The Federal Provincial Sub-Committee on Radiation Surveillance is currently assessing and developing guidelines for internal contamination by specific radionuclides.

A safety program followed by one U.S. company that embraces nuclear fuels, the seabed disposal of radioactive wastes, reactor safety and the transportation of fission products was of interest from the point of view of the very wide diversity of problems that are involved (Zak et al. 1975).

More recent developments in the field of laser and microwave technology and instrumentation have focussed more attention on the field of non-ionizing radiation. The document "Health Aspects of Radiofrequency and Microwave Exposure" by the Radiation Protection Bureau discusses in detail the health and safety implications of microwave exposure.

Another laboratory has documented the radiation safety considerations for work in laser research and other health hazards in a scanning electron microscopy laboratory (Thurston, 1978).

The standards that apply in Canadian federal institutions with respect to radiation hazards (in laboratories, hospitals, industry, etc.) are available as Safety Codes from the Radiation Protection Bureau, as listed on page 6.

Microbiology

An editorial in "The Lancet" a few years ago (Anon, 1976) began: "In much human endeavour yesterday's heroism is today's fool hardiness and tomorrow's criminal negligence." The article suggests that microbiology illustrates this statement very well, since some of the pioneers in microbiology were honoured by having their names given to the organism they worked with and which killed them. Another editorial reflects that "the road microbiological knowledge has indeed been paved with dead laboratory workers, including anatomists, pathologists and surgeons" (Anon, 1973).

Some of the epidemiological work in this field suggests that the microbiology laboratory ranks among the most dangerous places of laboratory work (Udall, 1974; Pike, 1976), and the pathologist handling infected specimens was the most susceptible (Harrington and Shannon 1975, 1977). The handling and control of infectious agents (Wedum et al. 1972) as regards to safety in the microbiology laboratory have been dealt with in a number of publications (Phillips, 1969; Powell, 1971; Simmons, 1978; Songer and Sullivan, 1974). A special report from one institution, commented on laboratory-acquired infections over a 16 year period (Sullivan et al, 1978). Aspects of laboratory operations noted frequently in liability suits were: needles (broken), fall (mostly from fainting), perforations and erroneous results due to incompetence, reporting without testing (fraud), incomplete testing and the mismatching of specimens with patient (Jordan, 1978).

The most publicized incidents of laboratory-acquired infections appear to involve smallpox, hepatitis and tuberculosis. A recent accidental death from smallpox occurred in England and sparked considerable controversy. Endemic smallpox was well on the way to being eradicated (Wade, 1978), and the report of the Shooter committee reviewing this case found fault with three responsible major organizations, the Dangerous Pathogens Advisory Group (DPAG), the World Health

Organization (WHO) and the Department of Medical Microbiology at the University of Birmingham, where the exposure occurred (Anon, 1979c).

It was felt that the smallpox death challenged presumptions of laboratory safety (Hawkes, 1979; Anon, 1979d; Anon, 1979e), and exactly how the virus escaped was ascertained (Anon, 1979h). The World Health Organization apparently had expressed serious doubts on the facilities in the smallpox laboratory in that they did not match those set out for the WHO definitive smallpox laboratories (Anon, 1979f). Fears were expressed that smallpox might re-emerge as an endemic disease and so continued work with the virus was considered to be essential (Anon, 1979g), although the question as to whether the smallpox virus should be allowed to survive was also debated (Foege, 1979).

Hepatitis infections of laboratory origin have been the subject of a great deal of publicity. One noteable report, in connection with an event that occurred in Canada, was the death of two technologists in 1972 at the University Hospital in Saskatoon (Dick, 1975). Decisive action by the administrative staff of the hospital warded off a hospital-wide panic, although not before extensive media coverage, questions in the House of Commons and a temporary withdrawal of their services by laboratory technologists. Epidemiological studies confirm the high hazard due to this pathogen (Grist, 1975 and 1978), and a number of publications have pointed out special groups at risk (Watson et al. 1973; Scheirmann et al. 1978; Grist, 1979). The occupational hazards of viral hepatitis and other infections has been recognized (Zuckermann, 1971; Grist, 1973; Harrington and Shannon, 1976) and certain laboratory procedures and reagents have been found to be potential sources of infection (Jones, 1967; McGilchrist, 1972). The risk for some ethnic groups may be higher than for others, according to one study (Leers, 1977), and special precautions for performing tests with hepatitis antigen and antibodies have been suggested (Schmidt and Lennette, 1972).

Apart from the more frequent comment on the infections discussed above, a number of reports have highlighted other specific organisms. Those that have appeared in the recent literature include Coccidioides immitis, gonococcal conjunctivitis, pulmonary tuberculosis, aspergilli and their toxins, Rocky Mountain spotted fever, rabies, arbovirus infections, "Legion Disease" and acquired deep mycoses (Fisher and Kane, 1973; Bruins and Tight, 1979; Engbaek et al., 1977; Harington, 1967; Johnson and Kadul, 1967; Oster et al., 1977; Winkler et al., 1973; Hanson et al., 1967; Winsten, 1976; Schwarz and Kauffman, 1977). In several of these papers and others the transmission of disease has been related to the laboratory generation of aerosols and this subject has been discussed in several communications (Anon, 1979e; Rutter and Evans, 1972). Aerosolisation can arise from a number of laboratory procedures such as blood taking, mixing or shaking, opening containers, centrifugation, pipetting and others.

Viral hazards from disposable containers (Zuckerman and Taylor, 1969) have been cited as a potential source of hazard, and the past and present hazards of working with infectious agents has been reviewed (Pike, 1978). Another source of hazard, that has been reviewed, is laboratory cell lines (Martin et al., 1970; Martin et al., 1971).

Reports concerned with safety programs and the handling of highly infectious material have appeared in the literature and provide useful guidelines for the formulation of protective procedures (Gomperts et al., 1978; Stark, 1975). The recent innovations in genetic engineering have led to extensive discussion of the potential hazards in this endeavour (Anon, 1973), and guidelines for research into recombinant DNA have been drawn up by the Canadian Medical Research Council (Mitchell and Kaplan, 1977).

Laboratory Animals

There was surprisingly little comment in the literature on the hazards of working with toxic substances in the laboratory animal facility. One paper, that has been cited previously in the section on carcinogens, demonstrated how a fluorescent tracer could be widely distributed during a chronic animal feeding study, and illustrated the need for special precautions in experimental operations of this kind (Sansone et al., 1977). Sansone and his co-workers have also studied hazards arising from the feeding of animals with volatile test chemicals (Sansone and Lisikoff, 1978) and have evaluated the respective merits of wire or solid bottom cages (Sansone and Fox, 1977). In addition to these kinds of hazard, it should be remembered that many animal diseases are zoonotic. An objective preventive medicine program, the logistics of each operation, personnel protection, disposal of infected or test animals and the procedures that include necropsy, the preservation of dead tissues and the use of anaesthetics, should all be reviewed by the safety committee (Edward, 1969).

Miscellaneous and Non-Specific

A large number of communications have addressed the question of safety or hazards in the laboratory. Some were responses to the implementation, or proposed implementation of safety legislation and represent the 'pros' and 'cons' as seen by individuals (Anon, 1978; Harper and Thompson, 1978; Collins, 1978; Christie, 1978; Harrington, 1978). These reports raise a number of objections with respect to inspections of laboratory facilities and the competence of safety officer personnel. They should be consulted by all those who are involved with laboratory safety or its implementation. One correspondent, in particular, was especially vehement in his appraisal of the recommendations of the "Howie report" (Department of Health Social Security, 1978) that was the product of a British Working

Group (Pilsworth, 1978). Other comments and opinions on safety in laboratories concerned analytical laboratories (Anon, 1977a, Anon, 1977b), chemical and medical laboratories (Warren, 1977), dental laboratories (Autian, 1972), and hospital laboratories (Brown and Souter, 1977; Frazer, 1972).

Some more specific topics relating to this subject concerned the hazards of mouth pipetting (Phillips and Bailey, 1966; Collins, 1980), vandalism in medical laboratories (Grant and Harrington, 1975) and mercurial poisoning in laboratories (Baron, 1974). A number of devices have filled a need in one of these areas of concern (Fuscoe, 1976) and the practice of pipetting by month should be discouraged. Another device related to the transport of "high risk" specimens has been described (Cash, 1971).

Finally, two excellent articles, that are well worth attention, address the question of meeting safety standards in the laboratory (Fried, 1977), and provide a guide to the implementation of laboratory safety (Douglas, 1976).

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